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The Honorable Reed E. Hundt
Chairman
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Dear Mr. Chairman:

The National Aeronautics and Space Administration hereby submits comments to the proposed Rulemaking entitled "Amendment of Parts 2 and 15 of the Commission's Rules to Permit Use of Radio Frequencies Above 40 GHz, for new Radio Applications," ET Docket No. 94-124, RM-8308.

Sincerely,

A handwritten signature in black ink, appearing to read "Charles T. Force", written over a horizontal line.

Charles T. Force
Associate Administrator for
Space Communications

Enclosure

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

In the Matter of

Amendment of Parts 2 and 15
of the Commission's Rules to Permit
Use of Radio Frequencies Above 40 GHz
for New Radio Applications

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ET Docket No. 94-124
RM-8308

COMMENTS OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Charles T. Force
Associate Administrator
Office of Space Communications
National Aeronautics and Space
Administration

January 30, 1995

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SUMMARY

NASA believes that it is timely to consider how frequencies above 40 GHz can best be used for the benefit of the American public and industry. NASA agrees with the Commission in its view that the proposals set forth in its NPRM will provide the American public with access to new products and communications services, provide new opportunities for American business and industry, and promote new jobs and economic growth in the United States.

NASA is in the forefront of development and use of millimeter wave devices for applications in space and we take a great deal of interest in the proposals contained in the instant Notice. We carry out environmental spaceborne remote sensing measurements using both active and passive sensors in the frequency regime above 40 GHz. We sponsor an active program to quantify the effects of propagation through the Earth's atmosphere on the properties of radio wave transmission and can therefore offer authoritative information to the Commission on the important mechanisms that need to be taken into account in the frequency range above 40 GHz.

NASA continues to develop high-risk, innovative technology for the benefit of U.S. industry and the American public. The latest communications satellite to be developed by NASA is the Advanced Communications Technology Satellite ("ACTS"), launched in September, 1993. ACTS has been designed to pioneer the 20/30 GHz K_a-bands for subsequent use by the American satellite communications industry. Thus, ACTS directly

benefits the constituency of the FCC: American industry and the American public.

NASA believes that the proposals in the subject NPRM can provide the basis for solving the incompatibilities that would exist in the 27.5-29.5 GHz band were that band to be allocated to both the Fixed-Satellite Service (FSS) and to a new Local Multipoint Distribution Service ("LMDS") as contemplated in CC Docket No. 92-297. The effect of the Commission's proposals in the instant NPRM would be to create a band at 40.5-42.5 GHz with virtually the same conditions as that proposed at 27.5-29.5 GHz. The same 2 GHz of bandwidth would be established, to be licensed in the same 1000 MHz blocks. The propagation environment at 40 GHz is similar to that in the nearby 28 GHz band as are the equipment parameters. Only the name has changed from LMDS to LMWS.

NASA believes that the Commission's proposal for commercial use of the 40.5-42.5 GHz band is the key to resolving the severe incompatibility problems that exist between the FSS and the LMDS in the 27.5-29.5 GHz band. Use of the 40.5-42.5 GHz band for LMDS in lieu of the 27.5-29.5 GHz band would result in a win-win situation for the American public and for American industry. The satellite industry would be free at 27.5-29.5 GHz to build on the technologies pioneered by NASA's ACTS to fill an essential role in the National/Global Information Infrastructure (NII/GII). At the same time, LMDS could be developed without interference from the FSS in the 40.5-42.5 GHz band. American industry would have the opportunity to participate in two global markets rather than none since the FSS is allocated in the 27.5-29.5 GHz band on a global basis and the functionally equivalent European version of LMDS is being developed in the 40.5-42.5 GHz band.

The frequency range from 50 to 65 GHz is of particular interest to the Earth environmental science and meteorological communities because of the presence of unique atmospheric oxygen absorption lines that are located in this region of the spectrum. Spaceborne passive sensor measurements in the vicinity of these lines are used to develop atmospheric temperature profiles. Judicious selection of the measurement frequencies determines the altitudes in the atmosphere at which temperature measurements are obtained.

The Commission requests comment on whether terrestrial use of the 60.4-61.4 GHz band would interfere with planned spaceborne passive sensor measurements of atmospheric temperature. NASA has analyzed the sharing potential and concludes that, in this frequency range where measurements provide data on temperatures in the mesosphere, sharing is feasible.

The proposed use of 116-117 GHz and 122-123 GHz bands for unlicensed devices gives NASA a great deal of concern because both of these bands fall within the 116-126 GHz band allocated for the Earth exploration-satellite (passive) and space research (passive) services. We recommend that either alternative bands, outside bands allocated for passive sensing, be chosen in place of the 116-117 GHz and 122-123 GHz bands or that the transmitter power in these two bands be limited to -16 dBW in order to achieve compatibility.

The NASA propagation research program publishes a handbook on propagation effects for satellite systems design in the frequency range between 10 and 100 GHz. While this handbook is directed particularly to satellite system designers, most of the information applies equally to terrestrial communications links. We

believe that the contents of this document can be valuable to the Commission as it plans how to allocate, license and use frequencies above 40 GHz. For that reason, we are appending the NASA handbook to these comments.

**Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554**

In the Matter of

Amendment of Parts 2 and 15)	
of the Commission's Rules to Permit)	ET Docket No. 94-124
Use of Radio Frequencies Above 40 GHz)	RM-8308
for New Radio Applications)	

**COMMENTS OF THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION**

The National Aeronautics and Space Administration ("NASA") hereby submits its comments in response to the Notice of Proposed Rulemaking (NPRM) issued in the above-captioned proceeding.

I. INTRODUCTION

NASA agrees with the Commission in its view that the proposals set forth in its NPRM will provide the American public with access to new products and communications services, provide new opportunities for American business and industry, and promote new jobs and economic growth in the United States.

NASA is in the forefront of development and use of millimeter wave devices for applications in space and we take a great deal of interest in the proposals contained in the instant Notice. We carry out environmental spaceborne remote sensing measurements using both active and passive sensors in the frequency regime above 40 GHz. We sponsor an active program to quantify the effects of propagation through the Earth's atmosphere on the properties of radio wave transmission and can therefore offer authoritative information to the Commission

on the important mechanisms that need to be taken into account in the frequency range above 40 GHz.

NASA continues to develop high-risk, innovative technology for the benefit of U.S. industry and the American public. The latest communications satellite to be developed by NASA is the Advanced Communications Technology Satellite ("ACTS"), launched in September, 1993. It operates in the 20/30 GHz bands ("Ka-band") allocated world-wide to the Fixed-Satellite Service ("FSS") and designated in the United States for non-government use¹. ACTS has been designed to pioneer these bands for subsequent use by the American communications industry. Thus, ACTS directly benefits the constituency of the FCC: American industry and the American public.

The payoff for this important investment by NASA on behalf of the American taxpayer, in the form of new Ka-band satellite communications services and ensuring that the U.S. remains the world leader in satellite communications, requires continued access to Ka band frequencies for the American satellite industry.

NASA believes that the proposals in the subject NPRM can provide the basis for solving the incompatibilities that would exist in the 27.5-29.5 GHz band were that band to be allocated to both the Fixed-Satellite Service (FSS) and to a new Local

¹ Specifically, ACTS uplinks operate on 29.242 GHz (+/- 20.5 MHz), 29.263 GHz (+/- 20.5 MHz), and 29.298 GHz (+/- 20.5 MHz).

Multipoint Distribution Service ("LMDS") as contemplated in CC Docket No. 92-297².

Certain of the frequency bands above 40 GHz that the Commission proposes to reallocate are allocated and used for spaceborne passive remote sensing. A wealth of knowledge about the technical and operational aspects of remote sensing has developed since these frequency bands were first allocated at the 1979 World Administrative Radio Conference (WARC). We have analyzed the potential for sharing between passive spaceborne sensors and the terrestrial devices proposed in this NPRM. We conclude, in response to the Commission's request for comment concerning the 60.4-61.4 GHz band, that sharing is feasible in this band. However, the proposed use of 116-117 GHz and 122-123 GHz bands for unlicensed devices gives NASA a great deal of concern. We believe that either alternative bands should be chosen for unlicensed devices or that limits should be placed on the transmitter power of unlicensed devices in these two bands in order to achieve compatibility.

II. THE 40.5-42.5 GHz BAND SHOULD BE DESIGNATED FOR LMDS IN LIEU OF THE 27.5-29.5 GHz BAND

The Commission has stated that it believes that many of the uses of spectrum above 40 GHz will be technically and operationally similar to those fixed point-to-point services for video, voice and data transmission to subscribers throughout an area that have been proposed for LMDS in the 28 GHz band³. It therefore

² **See Rulemaking to Amend Part 1 and Part 21 of the Commission's Rules to Redesignate the 27.5 - 29.5 GHz Frequency Band and to Establish Rules and Policies for Local Multipoint Distribution Service, CC Docket No. 92-297, Notice of Proposed Rulemaking, Order, Tentative Decision and Order on Reconsideration, 8 FCC 557 (1993).**

³ **NPRM at para. 23.**

proposes licensing rules similar to those proposed for LMDS. The net effect of these proposals would be to create a band at 40.5-42.5 GHz with virtually the same conditions as that proposed at 27.5-29.5 GHz. The same 2 GHz of bandwidth would be established, to be licensed in the same 1000 MHz blocks. The propagation environment at 40 GHz is similar to that in the nearby 28 GHz band as are the equipment parameters. Only the name has changed from LMDS to LMWS.

The Commission currently has a Rulemaking proceeding underway to consider the redesignation of the 27.5-29.5 GHz band for a new LMDS on a co-primary basis with the FSS⁴. A group of experts recently met under the auspices of an FCC Negotiated Rulemaking Committee (NRMC) to examine the feasibility of co-frequency sharing between the proposed LMDS and the FSS⁵. The committee was to formulate rules, if possible, to maximize the co-frequency sharing. Despite the intense efforts of this group of experts, it was not possible to devise a method that would make co-frequency sharing feasible.

NASA believes that the Commission's proposal for commercial use of the 40.5-42.5 GHz band is the key to resolving the severe incompatibility problems that would be created were the 27.5-29.5 GHz band to be allocated on a co-primary basis to the FSS and the LMDS. Use of the 40.5-42.5 GHz band for LMDS in lieu of the 27.5-29.5 GHz band would result in a win-win situation for the American public and for American industry. The satellite industry would be free at 27.5-29.5 GHz to build on the technologies pioneered by NASA's ACTS to fill an essential role in

⁴ **Local Multipoint Distribution Service, 9 FCC Rcd 1394 (1994).**

⁵ **NASA was a member of the NRMC.**

the National/Global Information Infrastructure (NII/GII). Indeed, Hughes, Teledesic and Iridium already have applications before the Commission to develop global satellite networks in this frequency band. At the same time, LMDS could be developed without interference from the FSS in the 40.5-42.5 GHz band. American industry would have the opportunity to participate in two global markets rather than none since the FSS is allocated in the 27.5-29.5 GHz band on a global basis and the functionally equivalent European version of LMDS⁶ is being developed in the 40.5-42.5 GHz band.

Propagation considerations

One question that might reasonably be raised would be about the effect of propagation on LMDS if LMDS were to operate at 41 GHz rather than at 28 GHz. An examination of the design of a leading contender for LMDS⁷ proves conclusively that there is virtually no difference in the operation of LMDS at the higher frequency.

The propagation effects that need to be examined as functions of frequency are attenuation due to atmospheric gasses and attenuation due to precipitation.⁸ The attenuation due to water vapor and oxygen over the maximum distance of 4.8 km from hub to subscriber in the proposed system, while insignificant at both

⁶ Designated as the Multipoint Video Distribution System (MVDS).

⁷ Suite 12 system characteristics as documented in "Report of the LMDS/FSS 28 GHz Band Negotiated Rulemaking Committee", Appendix 6, Section 2.1, September 23, 1994.

⁸ See CCIR Report 338-5, "Propagation Data and Prediction Methods Required for Line-of-Sight Radio-Relay Systems".

frequencies⁹, is a mere 0.25 dB more at the higher frequency. This increased loss is more than offset by the 3 dB higher gain in the vertical plane that the same physical aperture antenna will provide at 41.5 GHz compared to 28.5 GHz.

The effect on availability of an LMDS hub to subscriber link in New York due to attenuation caused by precipitation has also been evaluated. The hub and subscriber are assumed to be separated by the maximum distance of 4.8 km. The subject design has a 13 dB margin to compensate for rain attenuation. For a uniform rain rate over the path, the available margin of 13 dB will just compensate for a specific attenuation due to rain of 2.7 dB/km. CCIR Report 721-2 provides the information that this specific attenuation corresponds to a rain rate of 14.9 mm/hr at 28.5 GHz. New York lies in Crane rain climate region D2¹⁰ where rainfall rates of 14.9 mm/hr are exceeded for no more than 0.1 % of an average year. At 41.5 GHz, taking into account the increase in hub antenna gain compared to that at 28.5 GHz, we find an available margin of 16 dB which will compensate for a specific attenuation due to rain of 3.33 dB/km. This rain rate corresponds to a rainfall rate of 10.5 mm/hr and is exceeded in New York for 0.16 % of the year.

The preceding analysis shows that there is an insignificant difference in the availability of the LMDS hub to subscriber link at 41.5 GHz compared to that at 28.5 GHz. The availability of the link is 99.9 % at 28.5 GHz and 99.84 % at 41.5

⁹ The sum of attenuation due to oxygen and water vapor over a 4.8 km path for a water vapor density of 7.5 g/m³ is 0.47 dB at 28.5 GHz and 0.72 dB at 41.5 GHz.

¹⁰ Crane, R.K., "Prediction of Attenuation by Rain", IEEE Trans. Comm., Vol. COM-28, No. 9, pp. 1717-1733, 1980.

GHz¹¹. The availability is, of course, higher for the great majority of hub to subscriber links at shorter distances. Even this small effect could easily be compensated for, if desired, by the use of power control at the hub.

Reflectivity Properties

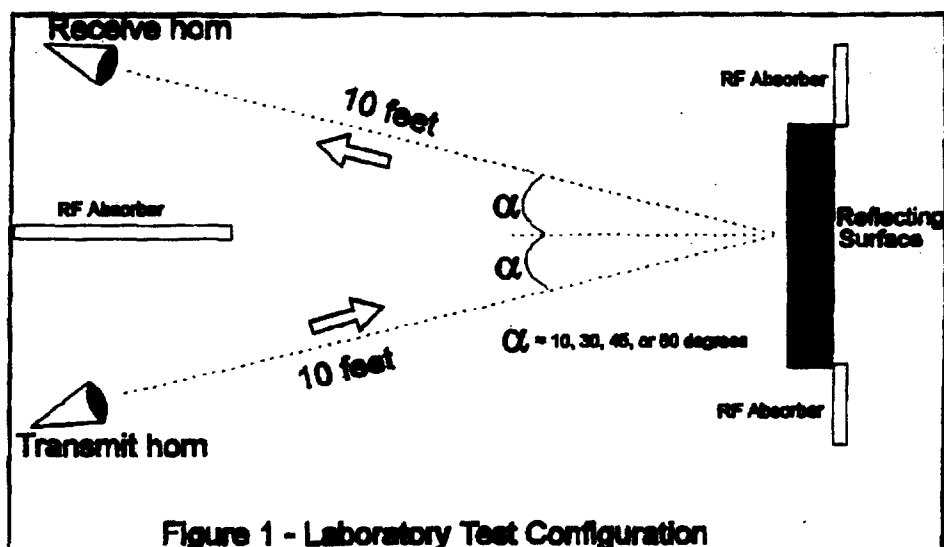
At least one LMDS proponent expects to partially rely on reflected signals to provide adequate signals between hub and subscriber terminals.

Laboratory experiments have been conducted at NASA's Lewis Research Center to assess reflective properties of various materials commonly used in building construction as a function of frequency. Specifically, the tests were designed to examine the behavior of reflected signals in the 28 GHz to 40 GHz frequency range.

The laboratory test configuration is shown in Figure 1. Standard waveguide horns, specified for use in the frequency range 26.5-40 GHz were aligned at angles of 10, 30, 45 and 60 degrees from perpendicular to four different reflective surfaces; unpainted concrete block, a flat metal sheet, unpainted plywood, and a glass mirror. The transmit and receive waveguide horns were each positioned at a distance of 10 feet from the center of the reflective wall¹².

¹¹ These availabilities exceed the criterion of 99% of the worst month, equivalent in New York to 99.7% of the year, established for Direct Broadcasting Satellites (DBS).

¹² The far field for the waveguide horns begins at 5-7 feet over the frequency range between 26.5 GHz to 40 GHz.



For the first series of tests, measurements were made at 28.5 GHz and 39 GHz¹³. First, a 28.5 GHz signal was transmitted and the received power level was measured with the spectrum analyzer. Next, the signal generator was switched to 39.0 GHz and the received power level was again recorded while keeping all other parameters constant.

The second series of tests consisted of performing a swept amplitude response test over the entire 26.5 GHz to 40 GHz band. Measurements were made at the same angles of incidence and reflection and for the same reflective surfaces as used for the previous tests.

All of our measurements were made of reflected signals in the specular direction. As would be expected the metal and mirrored glass surfaces

¹³ Measurements were made at 39 GHz rather than 41.5 GHz in order to remain within the specified range of the calibrated standard horn.

reflected more signal energy than wood or concrete block¹⁴. These surfaces also provided greater uniformity in reflected signal strength when swept across the frequency range.

Our measurements indicate that, for smooth surfaces such as metal and mirrored glass, only slightly greater reflection of both wanted and interfering signals occurs at 28.5 GHz compared to 39 GHz (and by extension at 40.5-42.5 GHz). For rough surfaces such as concrete block, brick, wood and stone, commonly used in both suburban and metropolitan construction, the results show that neither 28.5 GHz nor 39 GHz demonstrated consistently better reflecting properties.

On the basis of these measurements, it is concluded that non-line-of-sight performance for an LMDS system operating at 40 GHz would be substantially the same as operation at 28 GHz¹⁵.

Licensing rules

We note the proposal to designate the 40.5-42.5 GHz band for licensed use and to model licensing rules for this and other licensed bands after the rules and procedures proposed for LMDS. We think that these proposals are entirely fitting and to be the key to use of this band for LMDS in lieu of the 27.5-29.5 GHz band.

¹⁴ The reflected signal levels from the block and wood surfaces were generally 10-16 dB below those from metal and mirror for both 28.5 GHz and 39 GHz.

¹⁵ The results of these tests call into question statements made regarding signal bounce in "LMDS is not Viable in the 40.5-42.5 GHz Band", an ex parte submission by The Suite 12 Group in CC Docket No. 92-297.

The Commission may want to evaluate whether use of Rand McNally Major Trading Areas (MTAs) as the service areas rather than Rand McNally Basic Trading Areas (BTAs) is appropriate in light of probable use of the band for LMDS.

LMDS rules have not yet been finalized and some changes may be desirable. If rules are modified for LMDS, these are the rules that should be applied to the 40.5-42.5 GHz band.

Technical standards

The technical standards proposed for licensed services are generally compatible with planned LMDS signal parameters as presented to the FCC Negotiated Rulemaking Committee. However, one parameter, e.i.r.p., requires attention. The proposed limit of 16 dBW, while adequate for the majority of LMDS links, is lower than the value that some LMDS proponents have said was needed for certain of their links¹⁶. One proponent submitted e.i.r.p. values ranging from 10 to 28 dBW in the absence of rain and from 29.7 to 38 dBW in rain. E.i.r.p. levels for a second proponent ranged from -7 dBW to 23 dBW in the absence of rain and from 5 to 35 dBW in rain. The third system considered by the Committee had e.i.r.p. values between -10 dBW and 10 dBW for all links, well within the limit proposed in the instant NPRM.

¹⁶ "Report of the LMDS/FSS 28 GHz Band Negotiated Rulemaking Committee", Appendix 6, Table 2.3.1 - Signal Parameters WG1/52, September 23, 1994.

Section 33 of the NPRM actually may be adequate and appropriate for LMDS in the 40.5-42.5 GHz band since it indicates that e.i.r.p. levels above 16 dBW will be considered on a case-by-case basis subject to coordination with affected licensees. The resulting homogeneity between systems would minimize interference between licensees. On the other hand, the Commission might find it appropriate to consider a higher limit, at least during rain, in order to accommodate a wider range of system parameters and, in particular, power control.

III SHARING OF THE 60.4-61.4 GHz BAND BY SPACEBORNE PASSIVE SENSORS AND PROPOSED TERRESTRIAL USE IS FEASIBLE

The Commission requests comment on whether terrestrial use of the 60.4-61.4 GHz band would interfere with planned spaceborne passive sensor measurements of atmospheric temperature¹⁷. NASA has analyzed the sharing potential and concludes that sharing is feasible.

The frequency range from 50 to 65 GHz is of particular interest to the Earth environmental science and meteorological communities because of the presence of unique atmospheric oxygen absorption lines that are located in this region of the spectrum. Spaceborne passive sensor measurements in the vicinity of these lines are used to develop atmospheric temperature profiles. Judicious selection of the measurement frequencies determines the altitudes in the atmosphere at which temperature measurements are obtained. The 60.4-61.4 GHz band is used for mesospheric temperature measurements at heights between approximately 45

¹⁷ NPRM at para. 12.

km and 70 km. The Commission's NPRM proposes to designate the 59-64 GHz band for use by unlicensed devices. The band 60.4-61.4 GHz is located within this band.

The passive sensor measurements will obtain temperature data from the mesosphere. We have assumed the use of 'pushbroom sensors' in our analysis. This new class of passive sensor can achieve greater measurement sensitivity but is more susceptible to interference than conventional scanned sensors¹⁸. The interference threshold of pushbroom sensors is -166 dBW in a reference bandwidth of 100 MHz. The antenna and orbit parameters of the Advanced Microwave Sounding Unit (AMSU) were assumed for this analysis¹⁹. The AMSU has an antenna with a 15 cm diameter having a gain of 36 dBi and producing a pixel having a diameter at nadir of 49 km. AMSU will be placed in orbit at an altitude of 850 km.

The Commission proposes that unlicensed devices (except vehicular radars) be limited to a peak power density of 200 nanowatts/cm² at a distance of 3 meters from the antenna. As pointed out in the NPRM, this power density is comparable to an e.i.r.p. of 0.25 w.

¹⁸ Recommendation ITU-R SA.1029, "Interference Criteria for Satellite Passive Remote Sensing", specifies a permissible interference level of -166 dBW in a reference bandwidth of 100 MHz for pushbroom sensors in the frequency range of 50 to 66 GHz compared to -161 dBW for conventionally scanned sensors.

¹⁹ The first AMSU will be placed in orbit on a NOAA satellite during 1995. It will not have a capability to take measurements in the 60.3-61.3 GHz band. This feature will be added to future versions of the AMSU.

Zenith attenuation exceeds 200 dB at the peaks of the oxygen absorption lines between 60.3 and 61.3 GHz²⁰.

The interference level caused by a single transmitter with parameters conforming to those proposed in the NPRM can be readily calculated to be equal to -357 dBW compared to the sensor interference threshold of -166 dBW. Up to 1.26×10^{19} of these transmitters could be located in the main beam of an improved AMSU sensor without causing interference.

It is readily apparent that the proposed terrestrial use of the 59-64 GHz band will not interfere with passive sensor operations in the 60.3-61.3 GHz band.

IV. COMMENTS ON ALLOCATION OF 116-117 GHz and 122-123 GHz FOR UNLICENSED DEVICES

The proposed use of 116-117 GHz and 122-123 GHz bands for unlicensed devices gives NASA a great deal of concern. Both of these bands fall within the 116-126 GHz band allocated for the Earth exploration-satellite (passive) and space research (passive) services. There is an oxygen absorption line at 118.7 GHz which is much weaker than those in the vicinity of 60 GHz but still of use for passive spaceborne sensing. Our analysis shows that, in contrast to the situation at 60 GHz, only 1585 0.25 w transmitters directed at zenith would reach the interference threshold of our reference sensor design. We think it is probable that more than this number of unlicensed transmitters could be found in areas of 7500 km², the area on the Earth subtended by the sensor antenna mainbeam.

²⁰ CCIR Report 719-2.

We recommend that either alternative bands, outside bands allocated for passive sensing, be chosen for unlicensed devices in place of the 116-117 GHz and 122-123 GHz bands or that the transmitter power in these two bands be limited to -16 dBW in order to achieve compatibility.

V. PROPAGATION IMPAIRMENTS IN THE 10 TO 100 GHz RANGE

There is increasing use of frequencies above 10 GHz for all types of radio communications as evidenced by the Commission's release of an NPRM for use of frequencies above 40 GHz. These frequencies offer wider bandwidths, less congestion, and smaller components than bands at lower frequencies. These advantages can be rapidly offset, however, unless propagation impairments are understood and taken into account during system design. Important frequency impairments above 10 GHz, and even more so at frequencies above 40 GHz include rain attenuation, attenuation by atmospheric gasses including water vapor and oxygen, the effects of clouds and clear air, and tropospheric scintillation.

NASA has carried out a propagation research program spanning more than 2 decades to provide satellite system designers with information about the impairments that affect Earth-space communications. At the present time there is an active set of propagation experiments being conducted with the ACTS satellite to expand knowledge of the propagation environment at 20 and 30 GHz.

One product produced by the NASA program is a handbook on propagation effects for satellite systems design²¹. While this handbook is directed particularly to satellite system designers, most of the information applies equally to terrestrial communications links. We believe that the contents of this document can be valuable to the Commission as it plans how to allocate, license and use frequencies above 40 GHz. For that reason, we are appending the NASA handbook to these comments.

VI. CONCLUSION

WHEREFORE, the foregoing considered, NASA urges the Commission to:

- Take advantage of this NPRM to resolve the problems surrounding its proposals to establish an LMDS under CC Docket No. 92-297 by designating 40.5-42.5 GHz for LMDS in lieu of 27.5-29.5 GHz;**

²¹ NASA Reference Publication 1082(04), Fourth Edition, "Propagation Effects Handbook for Satellite Systems Design - A Summary of Propagation Impairments on 10 to 100 GHz Satellite Links With Techniques for System Design", Louis J. Ippolito, 1989.

- Either move the bands proposed for unlicensed devices at 116-117 GHz and 122-123 GHz out of the frequency band 116-126 GHz band allocated for passive sensors in the Earth exploration-satellite and space research services or limit the power of unlicensed devices in these bands to -16 dBW;

Respectively submitted,

**By:
Charles T. Force
Associate Administrator for
Space Communications
National Aeronautics and Space
Administration**

January 30, 1995

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Propagation Effects Handbook for Satellite Systems Design

*A Summary of Propagation
Impairments on 10 to 100 GHz
Satellite Links With Techniques
for System Design*

Louis J. Ippolito
Westinghouse Electric Corporation
Baltimore, Maryland

Fourth Edition


National Aeronautics
and Space Administration
Scientific and Technical
Information Division

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